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PATENT SPECIFICATION

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DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Improvements in and relating to Electric Cables and Apparatus Incorporating Such Cables.

We, RANSBURG ELECTRO-COATING CORP., an Indiana corporation, United States of America, of 3939 West 56th Street, Indianapolis, Indiana, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electrostatic coating apparatus, in which particles of coating material are deposited upon the article to be coated with the aid of a high voltage electrostatic field. The invention also has relation to electric cables for use at high voltage in such apparatus.

In the past, electrostatic coating apparatus has taken a number of different forms but in general use is made of an electrode or electrode system which is maintained at a high potential with respect to the article being coated, which is advantageously at earth potential. In those forms of apparatus which have had the widest commercial use the electrode is directly associated with the atomising means, such as a head assembly, of which the electrode may form part.

In a typical installation the potential applied to this electrode may be of the order of several tens of kilovolts, for example at least 30 or 40 kilovolts, and may be as high as 100 kilovolts or more. The use of such very high voltages on an electrode which must be at least to some extent exposed calls for particular consideration.

Disruptive discharges from the electrode are generally undesirable for obvious reasons, but in the case where the coating material is a paint or the like which contains the volatile and inflammable components, there may be a more positive danger of ignition or explosion of the vapour of the solvent in use. Apparatus of this kind also exists for use in the hand of an operator, or in conditions where it is possible for personnel to approach the electrode closely. In these cases there is the obvious danger of unpleasant shock, injury or worse to any person who may approach too closely.

In our prior specification No. 865,765, there is disclosed a spray-coating apparatus in which means are incorporated to reduce or eliminate these dangers, as may be required, such means comprising the use of a high value of resistance included in the electrical connection to the charged electrode.

As is pointed out in detail in that specification, the use of such resistance in conjunction with an electrode system that presents a low effective capacity will result in an improvement of the safety factor of the apparatus as regards fire or shock, and with appropriate values the apparatus can be made safe in either or both of these respects. In the specification referred to, there is included a description of an electrostatically operated spray gun, which, though making use of an electrode which in use is maintained at high potential, can be held safely in the hand, the voltage on the electrode decreasing rapidly on the approach of any earthed article, or any part of the person of the operator.

To secure this complete degree of safety it is essential that the effective electric capacity of the electrode and of any parts through which it is electrically connected should be kept to a low value. In this connection it is important to point out that the effective capacity of an electrode system is not the same as the conventional

tained at high potential, instead of embodying the customary highly conductive metal wire or the like for the transmission of the high voltage, employs a semiconductive element having a substantial distributed resistance. This element may conveniently consist of one or more layers of semiconductive polyethylene or the like preferably surrounding a flexible but relatively inextensible core and in turn surrounded by a layer of flexible insulating material. Desirably, the latter layer is surrounded by an earthed braided wire sheath, which may be covered by an abrasion-resistant, easily cleanable coating.

Other features and advantages of the invention will appear from the following description of embodiments thereof, given by way of example, in conjunction with the accompanying drawings, in which:—

Figure 1 is a somewhat diagrammatic view showing an electrostatic spray-coating apparatus employing a hand-held spray gun, and

Figure 2 is an elevation showing a preferred form of high-voltage cable with its various layers broken away.

The apparatus shown in Figure 1 comprises a spray gun, designated in its entirety by the reference numeral 10, a source 11 of paint or other coating material, and a power pack or high-voltage source 12. The particular spray gun shown in Figure 1 as an example of an electrostatic spraying device is of a type more fully illustrated and described in the aforesaid patent No. 865,765. It comprises an elongated body 15 of insulating material carrying at its rear end a handle member 16 having a conductive grip portion or handle 17 and at its front end a rotatable, electrically charged atomising head 18. Paint to be supplied to the interior of the head 18 is conveyed to the gun through a flexible hose 20, while power for rotating the head is transmitted through a cable 21. High voltage for charging the head is conducted to the gun through a flexible cable 22 and is applied to the head through a resistor 23 housed within the body 15 and electrically connected at its front end to the head by means of a brush 24. It is to be understood that this invention is not limited to any particular form of electrostatic spraying device and that the one illustrated is shown merely by way of example. It is particularly noted that the invention is not limited to a hand gun, or to a device in which a single element, in this case the rotating head 18, serves as both a spray-forming means and an electrode.

A preferred form for the high voltage cable, shown in detail in Figure 2, comprises a flexible, non-conductive central core 26 surrounded successively by a semiconducting layer 27, an insulating layer 28, a braided metal sheath 29, and an abrasion-resistant, easily cleanable, outer covering 30. As such cable is used in the apparatus of Figure 1, the metal sheath 29 is secured at its opposite ends to the gun and power pack, is electrically earthed, usually at the power pack, and electrically connected to the conductive handle 17 to earth it as well as the operator grasping it. The semiconducting cable-layer 27 is electrically connected to the high potential or unearthed terminal of the power pack and to the rear end of the resistor 23.

The semiconducting cable-layer 27 may be formed of polyethylene or some other similar flexible material incorporating carbon black or other finely comminuted material in proportion such as will give the layer the desired resistivity. The resistance of the layer 27 per foot of length will depend upon its cross-sectional area and its volume resistivity, and those factors are coordinated so that the resultant cable has an average resistance of not less than one and preferably in the range one to five megohms per foot. Of course, higher values of cable resistance can be tolerated, but if the resistances are appreciably higher, and if unusually long cables are used, compensating adjustments may be required in other circuit parameters. Since for a given operating voltage the insulating layer 28 must have a certain minimum thickness (about 3/16 of an inch has actually been used in cables for this type of equipment) in order to sustain the potential difference between the conductive layer 27 and the earthed sheath 29, the diameter of the conductive layer will limit the minimum diameter of the cable as a whole. For reasons of economy, and also to avoid undesirable rigidity in the cable, it is therefore desirable that the conductive layer 27 have a relatively small diameter. On the other hand its radial dimension determines the nature of the electrical gradient which exists across the layer 28 when the layer 27 is raised to high voltage. The larger the layer 27 the smaller will be the potential gradient at its surface; and if the layer 27 is too small, the potential gradient at its surface may be undesirably large. Taking all these factors into account, a layer 27 having a diameter of about one-eighth inch is appropriate for use with high voltage sources having an output in the neighbourhood of 50 to 100 kilovolts.

The purpose of the central core 26 is to prevent or limit stretching of the conductive layer during the course of cable-manufacture. Stretching of that layer would decrease its diameter and also effect the volume resistivity of the material such as

electrical capacitance of the system, but is that value of true capacitance which would make instantaneously available to support an electric discharge the same amount of energy as that in fact available from the cable. In stating that an element, such as the charging electrode or electrode system, or its equivalent, has a low effective capacity we mean that the element presents at a particular point such low true capacitance or such combination of true capacitance and electrical resistance that where the element is used in a high voltage apparatus of the character concerned, the energy contributed to disruptive discharge between such element and an opposed blunt electrode by the electricity stored in the system including the element is insufficient to render such discharge objectionable.

In a construction of a hand-held atomiser or spray gun, described in specification 865,765, an electrode of low effective capacity is arranged at the forward end of the elongated body of the atomiser. A high value resistor is connected at its forward end to the closely adjacent electrode and the rearward end of the resistor is connected to the high voltage supply through the central metal conductor of a flexible cable having an earthed conductive sheath. If the resistor has a resistance which is adequately high with respect to the applied voltage, and the effective capacity of the electrode is low, the increase in current which accompanies approach of the electrode to an earthed object will increase the voltage drop across the resistor at such a rate that the intensity of any sustained discharge that may occur from the electrode will be so low that it involves no objectionable shock or fire hazard.

While such apparatus may be made free from danger in respect to discharges that can occur from the electrode, it possesses a possible hazard in the flexible cable through which high voltage is applied to the resistor in the gun-body. In the use of such apparatus, the cable, which may have a length of many feet, commonly lies on the floor. In that position, the cable is subject to injury which might expose its central conductor or reduce the dielectric strength of its insulation. Such an accident could result in the occurrence of a high-intensity spark discharge between the central conductor and the earthed cable-sheath or any other earthed object; and in an atmosphere containing flammable vapours of the commonly used paint solvents such a spark could cause a fire. Although some resistance is sometimes incorporated in the high voltage supply, it is not possible to thereby eliminate, or reduce to a satisfactory extent, the hazard of a spark resulting from cable-rupture. While a resistance in the voltage supply can limit the intensity of a steady-state discharge, it cannot control the discharge of electrical energy stored in the cable beyond the resistance.

The present invention concerns a high-voltage cable for supplying the electrode of an electrostatic spray-painting apparatus maintained at high voltage, which reduces the hazard attendant upon cable-rupture. A cable in accordance with, or for use in a system in accordance with the invention can be given adequate flexibility and can be light in weight.

In one aspect, the present invention consists of electrostatic spray coating apparatus wherein an electrode which in operation is required to be maintained at a high voltage is electrically connected to the insulated conductor of a high voltage electric cable for connection to a source of said high voltage, said conductor having a uniformly distributed resistance of not less than one megohm per foot length of the cable.

The cable used in apparatus according to the invention is advantageously provided with an outer flexible conductive sheath, which may in turn be overlaid by a further and outer layer of insulating material. In this case the design of the cable is preferably such that it has a low effective capacity. The expression "low effective capacity" used in this specification and the accompanying claims is to be understood as meaning such a combination of true capacitance and resistance that the energy contributed to a disruptive discharge between the cable high-voltage conductor and earth will be insufficient to ignite a mixture of air and flammable vapour or to deliver an unacceptable electric shock to a normal operator.

The invention also comprises electrostatic spray-coating apparatus including an electrode connected to a source of high voltage by way of an electric circuit including the insulated conductor of an electric high-voltage cable, said conductor having a uniformly distributed resistance which is not less than one megohm per foot length of the cable. Specifically, this aspect of the invention contemplates an electrostatic spray coating apparatus wherein a spray charging electrode is connected with the output electrode of a high voltage source by way of an electric circuit wherein the major portion of the circuit resistance is represented by the resistance of said cable conductor.

In one construction in accordance with the invention the flexible cable through which the spray-charging electrode of an electrostatic spray-coating device is main-

to increase its resistance. The cross-sectional area of the conductive layer and the nature of the material forming the layer are such that, unless its stretching is controlled during its formation and the application to it of the insulating layer 28, the resistance of the layer per unit of length could vary to an undesirable extent. While there are other ways of controlling such stretching, the most convenient way is to form it as a coating on a core 26 of more or less relatively inextensible material. Coarse threads of natural or synthetic organic fibres, glass roving, and glass strand are suitable materials for the core 26. Of course, this core is not an essential portion of the invention.

The insulating layer 28 must possess adequate insulating properties as well as adequate flexibility. Polyethylene is a suitable material for that layer.

The function of the outer cable-layer or covering 30 is, as previously indicated, to protect the braided metal sheath 29 from abrasion and also to facilitate cleaning the cable. Suitable materials for that covering are the natural and synthetic rubbers, polyethylene and the like. However, such materials are normally good electrical insulators; and it is desirable that the covering 30 possess a measure of conductivity in order to prevent its acquisition of a surface charge as a result of impingement on it of atmospheric ions inevitably present in the vicinity of electrostatic coating apparatus. Suitable conductivity can be imparted to the covering 30 by incorporating an adequate proportion of carbon black or graphite in the material from which it is formed.

In the circuit between the high-voltage terminal of the power pack and an electrode of an electrostatic spray gun, the portion of the total resistance provided by the cable described will vary with circumstances. One successful system embodying a power pack of 60 kilovolts output and a hand-held spray gun provided with a spray-charging electrode employs a 160 megohm resistor mounted in the gun and connected to the power pack through a conventional metallic conductor. By replacing the conventional cable of that system with a cable according to this invention having a length of 32 feet and a distributed resistance of five megohms per foot, it is possible to eliminate the necessity for any additional resistor in the gun. Where it is impractical to employ a cable providing all the resistance directly connected to the electrode, the cable may, and desirably will, provide a major portion of such resistance: but although the cable-resistance may provide only a portion, even a minor portion, of the total resistance, it still has the advantage of making it possible to attain the desired degree of safety with a smaller resistor in the gun.

From the foregoing it will be apparent that in the event of the cable being ruptured or the high voltage conductor exposed in use, the danger of disruptive discharge will depend upon the effective capacity at that point. In the case of a conventional cable having a low resistance high voltage conductor it will be clear, as pointed out above, that the electrical capacity of the power pack and other circuit means directly connected to the conductor will contribute to the effective capacity at the point of exposure or rupture. By including resistance in the serial connection afforded by the cable, the effect of such associated capacity is largely reduced or eliminated. There remains the capacity of the cable itself, and for the complete elimination of the danger of shock or fire the cable itself must present at any point along its length a low effective capacity. A safe effective capacity is definable as one in which the energy contributable to a disruptive discharge beween the point of rupture or exposure of the high voltage conductor does not exceed that of a metallic sphere of three centimetres radius, at the same point and preferably does not exceed that of a sphere of one centimetre radius.

It follows that the cable in accordance with the present invention should have such combination of true capacitance and resistance as to have a low effective capacity at any point along its length.

Cables in accordance with this invention have been tested by rupturing the cable at various distances from the power pack. An explosion chamber containing an air-hexane mixture at 3°F. and atmospheric pressure was employed. A cable having a distributed resistance of 3.9 megohms per foot was connected with a power pack developing 100 KV output, with 130 megohms resistance in the pack in series between the high voltage point and the cable. Beginning with a 27 foot cable, the cable was cut shorter and shorter down to a 5 foot length without causing a discharge sufficient to ignite the hexane-air mixture.

In another example, a cable having a distributed resistance of 11.1 megohms per foot was connected to a power pack developing 150 KV with 480 megohms resistance in the pack between the high voltage point and the cable (pack resistance). Even when reduced to a length of only six feet, there was insufficient discharge to ignite the hexane-air mixture. The absence of a discharge capable of igniting the hexane-air mixture is indicative of the fact

that the effective capacity of the cable was less than that of a 1 cm. sphere.

In our prior specification No. 865,765, and as mentioned briefly above, the use of high resistance in the connection to the high voltage electrode of an electrostatic coating apparatus has an advantage that it secures a drop in the average potential gradient automatically, on the approach to the electrode of the article to be coated, or any other object at or near earth potential, or the potential of the other terminal of the high voltage supply. In our prior specification no. 865,766, it is pointed out that there is an optimum potential gradient for optimum atomisation with certain types of atomiser. The cable of the present invention can thus be used with advantage in a system in which safety from freedom or shock, considered at the electrode only, is not a primary requirement.

Another advantage of the cable 22 with its distributed resistance, as compared to the conventional cable with its metallic high-voltage conductor, is that the maximum voltage existing in the gun as a whole is reduced by the substantial voltage drop along the cable between the power pack and the gun. This simplifies the problem of providing, at the rear end of the gun, insulation or air-gap lengths adequate to take care of the potential difference between charged gun parts and the earthed handle.

In addition to the advantages just noted, a system employing the cable 22 is seen to have a further advantage when one considers the possible consequences of cable-rupture. In an electrostatic painting installation, the atomiser or atomisers are commonly located a substantial distance, for example fifteen or twenty feet or even more, from the power pack and the high voltage cable lies on the floor, where it is subject to injury as from falling objects or the passing of factory trucks over it. Should the insulating layer 28 be ruptured as the result of such an accident or from other causes, the exposure of the high-voltage conductor could result in an electrical discharge from the central conductor to the earthed metal sheath. If the central conductor were of metal, the energy stores in the capacity of the remaining cable lentgh at full power-pack voltage would be available to create an initial discharge which would therefore be relatively intense. In an atmosphere containing the flammable solvent vapours of commonly used paints, such an intense discharge could easily cause a fire. However, with a cable in accordance with this invention embodying a central conductive element having a high value distributed resistance, the capacity of the remaining cable section would be isolated from the point of discharge by this distributed resistance and the value of the initial as well as the steady state current would thus be limited by it. After the occurrence of the initial capacity discharge of low value the voltage drop between the power supply and the site of the rupture would be more than with a cable with a metallic core and thus the intensity of the steady state discharge would be materially limited and thereby reduce the fire hazard. In this connection, it may be noted that in an electrostatic spray-painting operation the greatest concentration of solvent vapours exists adjacent the atomiser, and if a cable-rupture occurred in that region practically the full resistance of the cable would be available to reduce the intensity of the electrical discharge. If the rupture occurred farther from the gun, less of the total cable resistance would be available and the discharge would be more intense; but, so far as likelihood of a fire is concerned, the increase in the intensity of the discharge would at least in part be offset by the lower concentration of solvent vapours at the point of rupture.

WHAT WE CLAIM IS:—

1. Electrostatic spray-coating apparatus wherein an electrode which in operation is required to be maintained at a high voltage is electrically connected to the insulated conductor of a high-voltage electric cable for connection to a source of high voltage, said conductor having a uniformly distributed resistance of not less than one megohm per foot length of the cable.

2. Electrostatic spray coating apparatus wherein an electrode is connected to a high-voltage source by way of an electric circuit including the insulated conductor of a high-voltage cable, said conductor having a uniformly distributed resistance of not less than one megohm per foot length of the cable.

3. Apparatus in accordance with claim 1 or claim 2 wherein said conductor has a uniformly distributed resistance of five megohms per foot length of the cable.

4. Apparatus in accordance with claim 1, claim 2 or claim 3 wherein said conductor is of a semiconductive material.

5. Apparatus in accordance with any of the preceding claims wherein said conductor has a core of non-conductive substantially inextensible material.

6. Apparatus in accordance with any of the preceding claims wherein said cable comprises an outer flexible conductive sheath.

7. Apparatus in accordance with claim 6 wherein said cable comprises a further

and outer layer of insulating material overlying said sheath.

8. Apparatus in accordance with claim 6 or claim 7 wherein said cable has a low effective capacity as hereinbefore defined such that any discharge of electricity therefrom which could present a fire hazard is avoided.

9. Apparatus in accordance with claim 6, claim 7 or claim 8, wherein said conductive cable sheath is earthed.

10. Apparatus in accordance with claim 2 wherein said circuit has a resistance of at least one megohm per kilovolt of the potential of said high-voltage source, said cable conductor presenting the major portion of said circuit resistance.

11. Electrostatic spray coating apparatus substantially as hereinbefore described with reference to the accompanying drawings.

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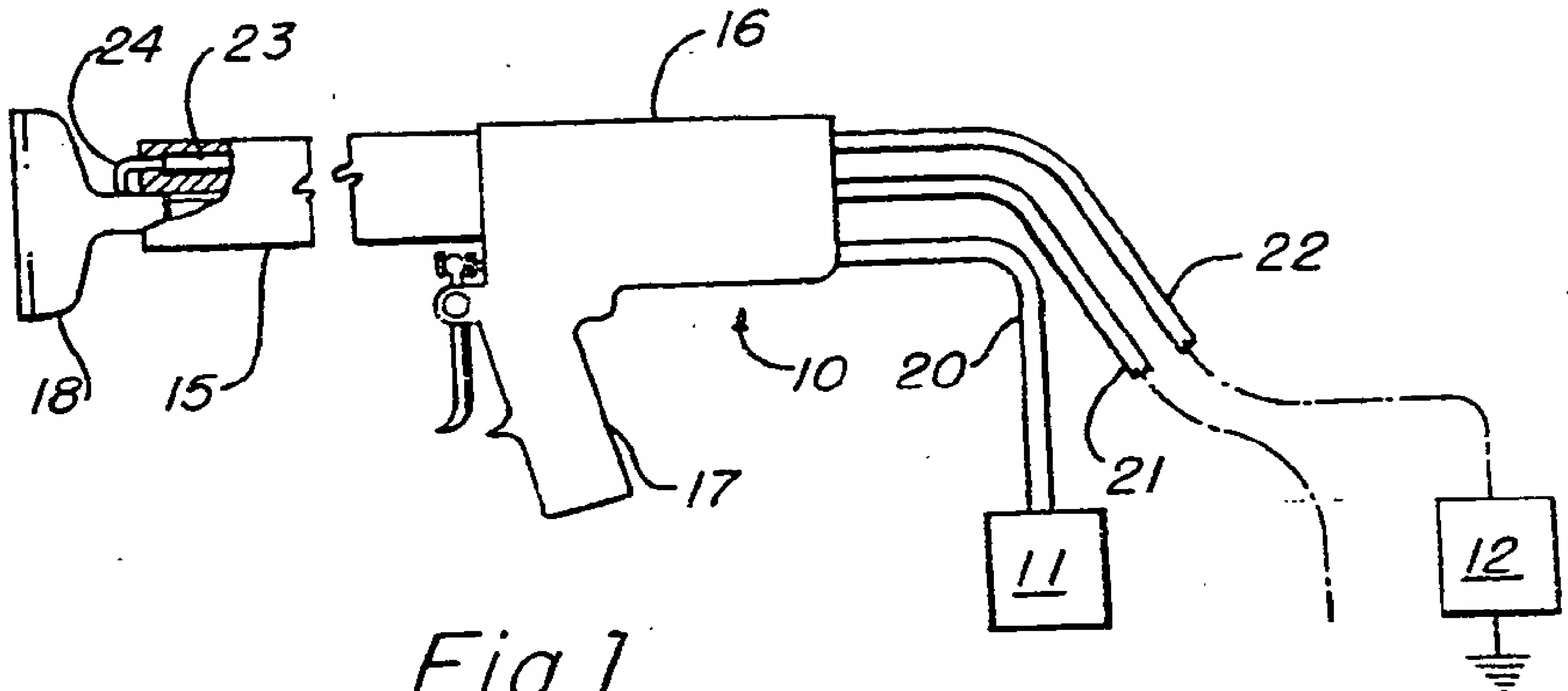

Fig.1

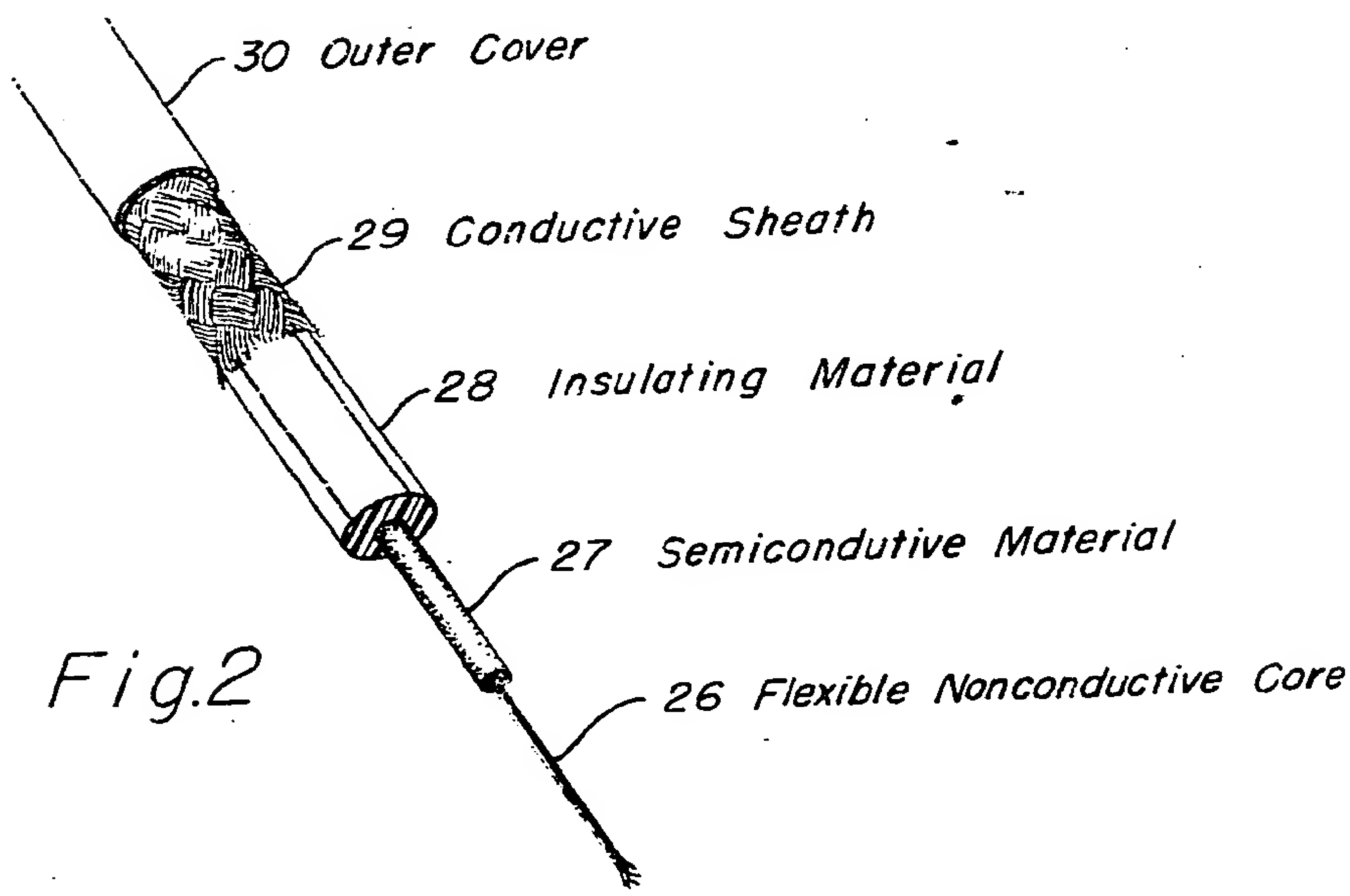

Fig.2